Development of EUVL Collector Technologies for Infrared Radiation Suppression

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INTEGRATED OPTICAL SYSTEMS

NIST
National Institute of Standards and Technology

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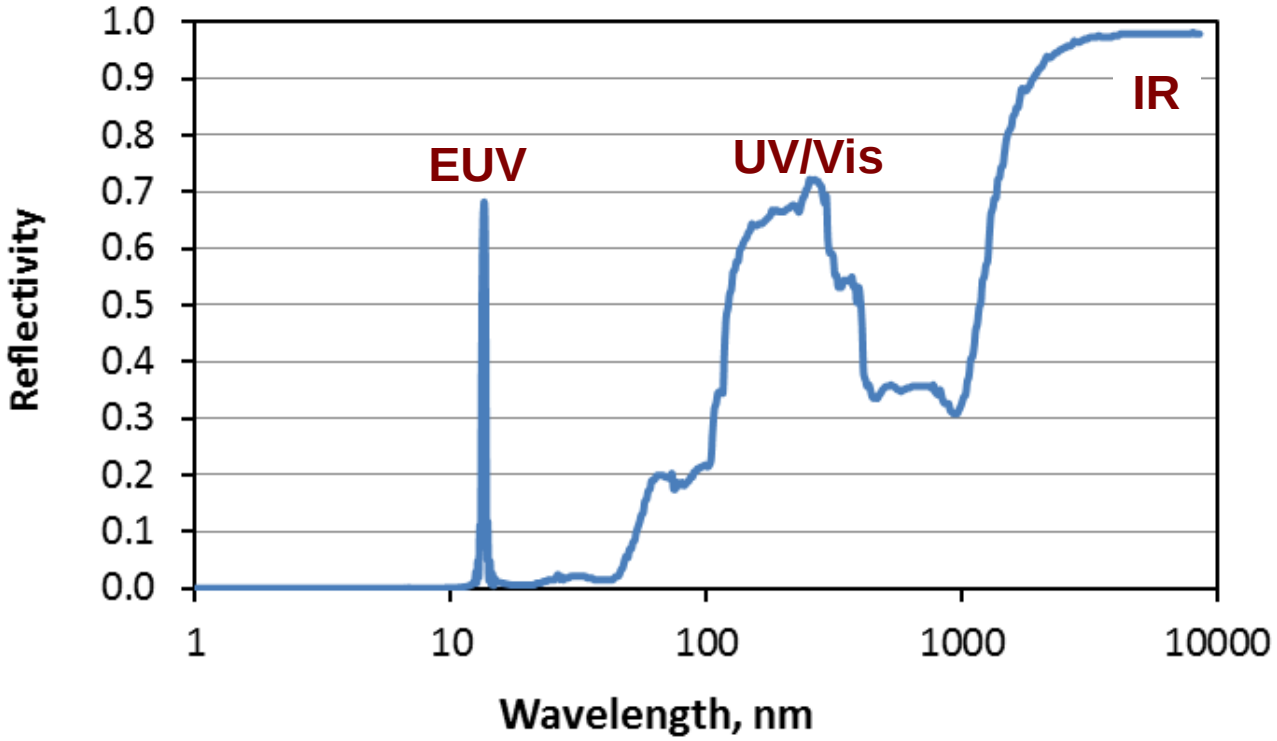
Osmic Inc.
a Rigaku company

- BACKGROUND
- MACHINING & FIGURING
- INFRARED REJECTION
- SMOOTHING LAYER
- NIST UPGRADE
- MULTILAYER RESULTS

Background

- LPP sources generate 10.6μm IR radiation
- Mo/Si ML optics reflect IR radiation through IF

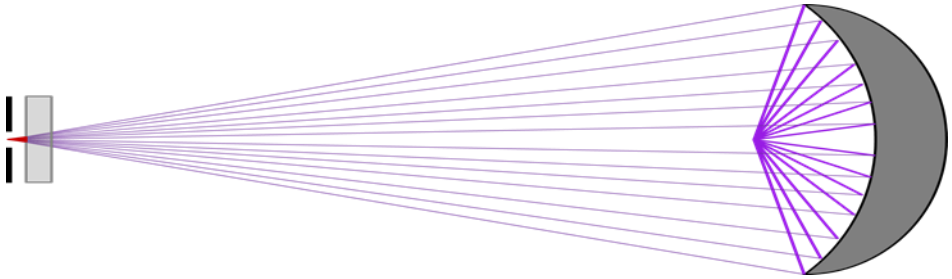


Methods to Reduce IR

Filter (IPM-RAS)

~ 30% EUV loss

~ 125X IR suppression

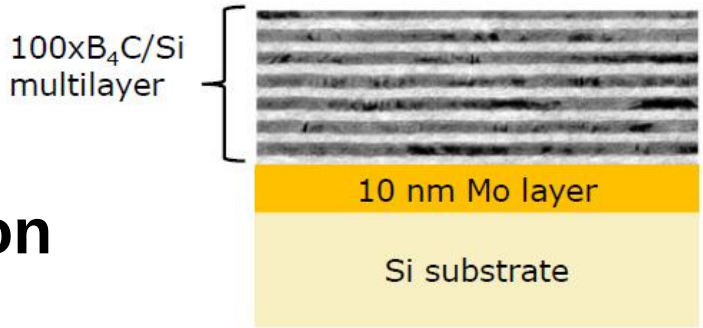


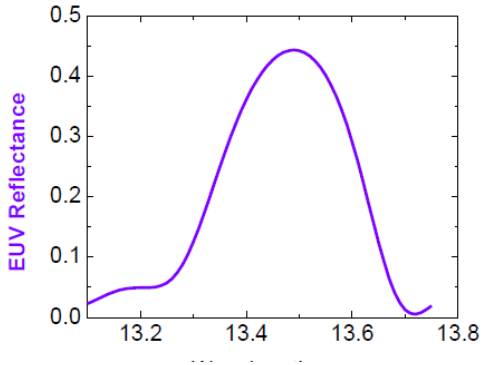
Chkhalo et. al., *Proc SPIE 8076 (2011)*

AR Layers (FOM)

~ 25% EUV loss

~ 250X IR suppression





Medvedev et. al., *Opt. Lett. 37, pg. 1169 (2012)*

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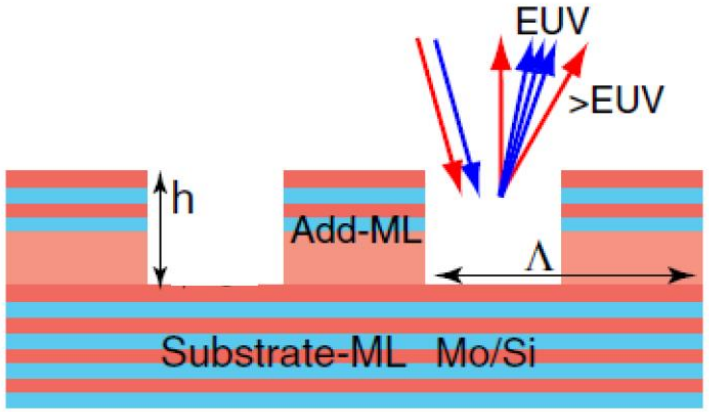
Methods to Reduce IR

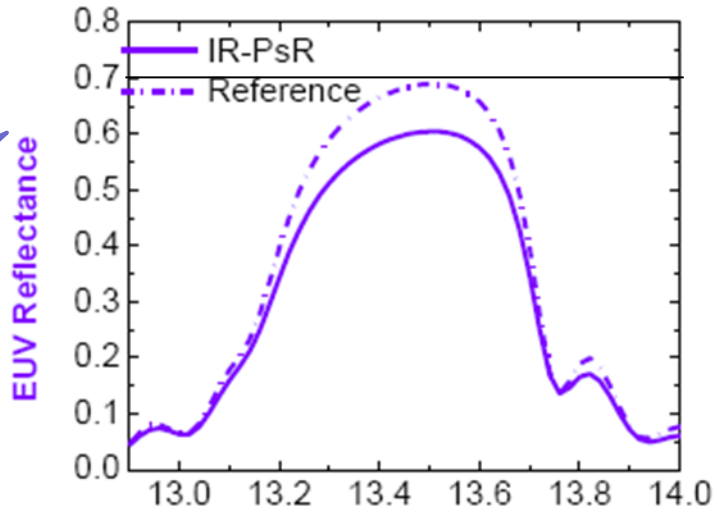
Diffraction Grating (FOM)

~ 8% EUV reduction

~ 70X IR suppression

Medvedev et. al., *Opt. Lett., 36, Issue 17, p. 3344 (2011) & 2012 International Symposium on Extreme Ultraviolet Lithography, Brussels, Belgium*





"Test Structure" Results
Rp 61%

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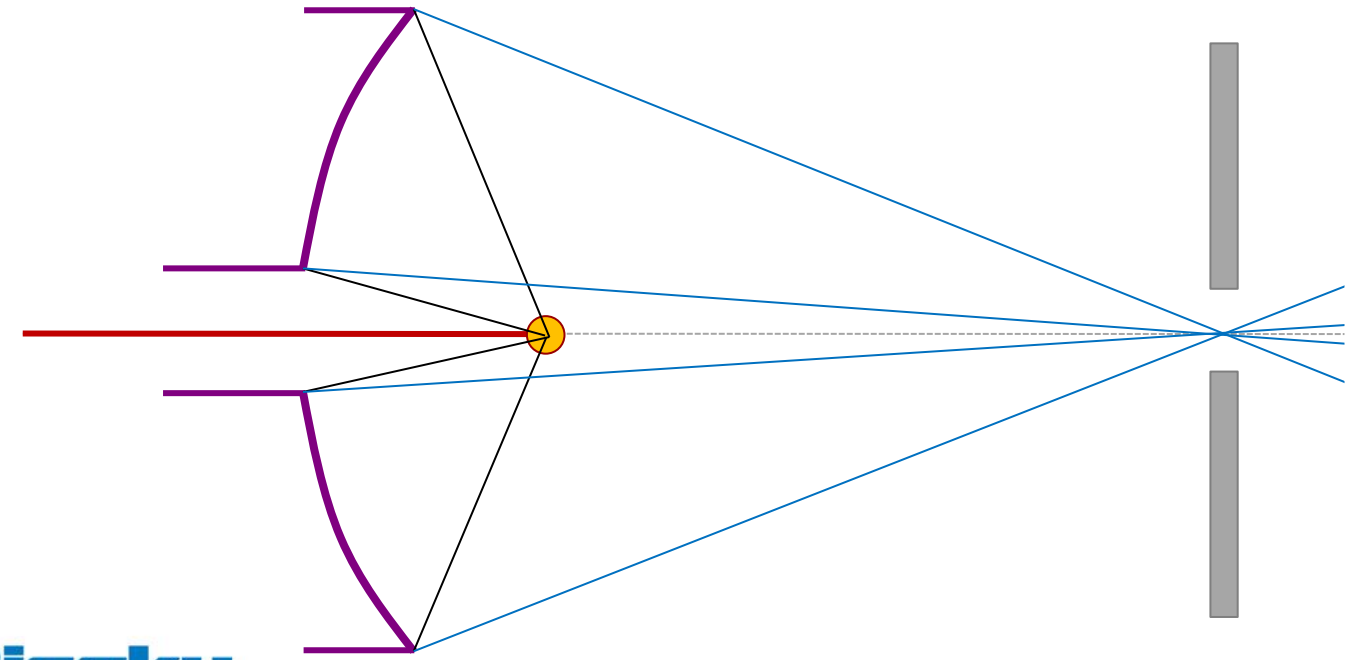
Achievement of the IRRC

(Infra-Red Rejection Collector)

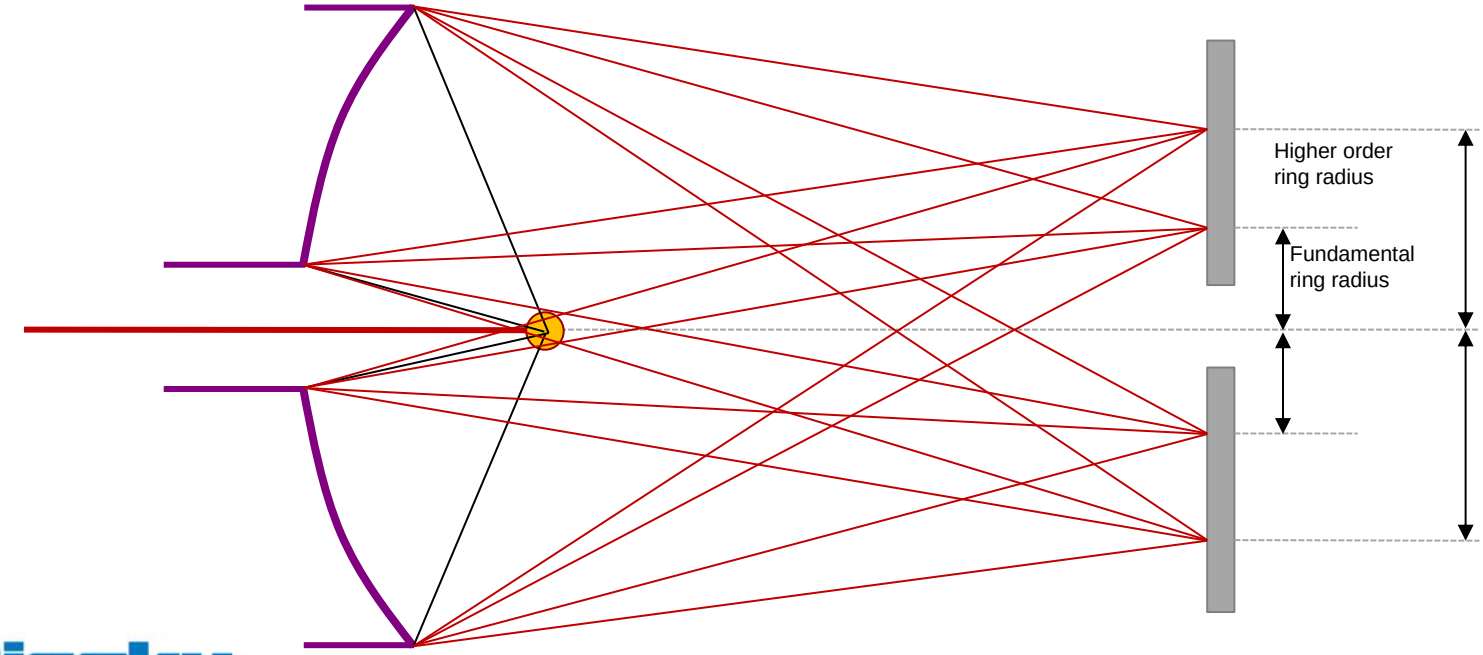
- Ellipsoidal collector with NA ≳ 0.22 surface with multilayer to focus 13.5nm



Achievement of the IRRC

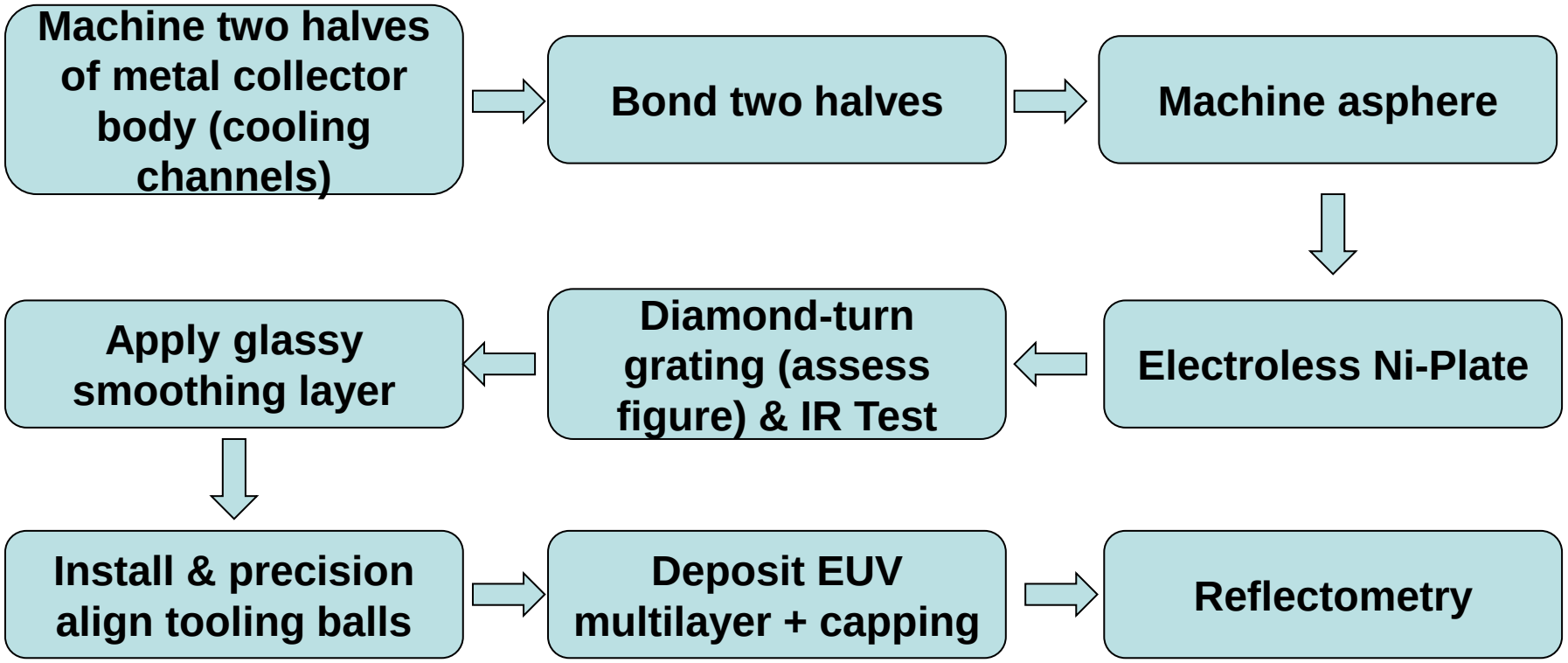
(Infra-Red Rejection Collector)

- Ellipsoidal collector with NA ≳ 0.22 surface with multilayer to focus 13.5nm
- Tuned grating directly on optical surface to diffract 10.6μm (IR) away from IF aperture

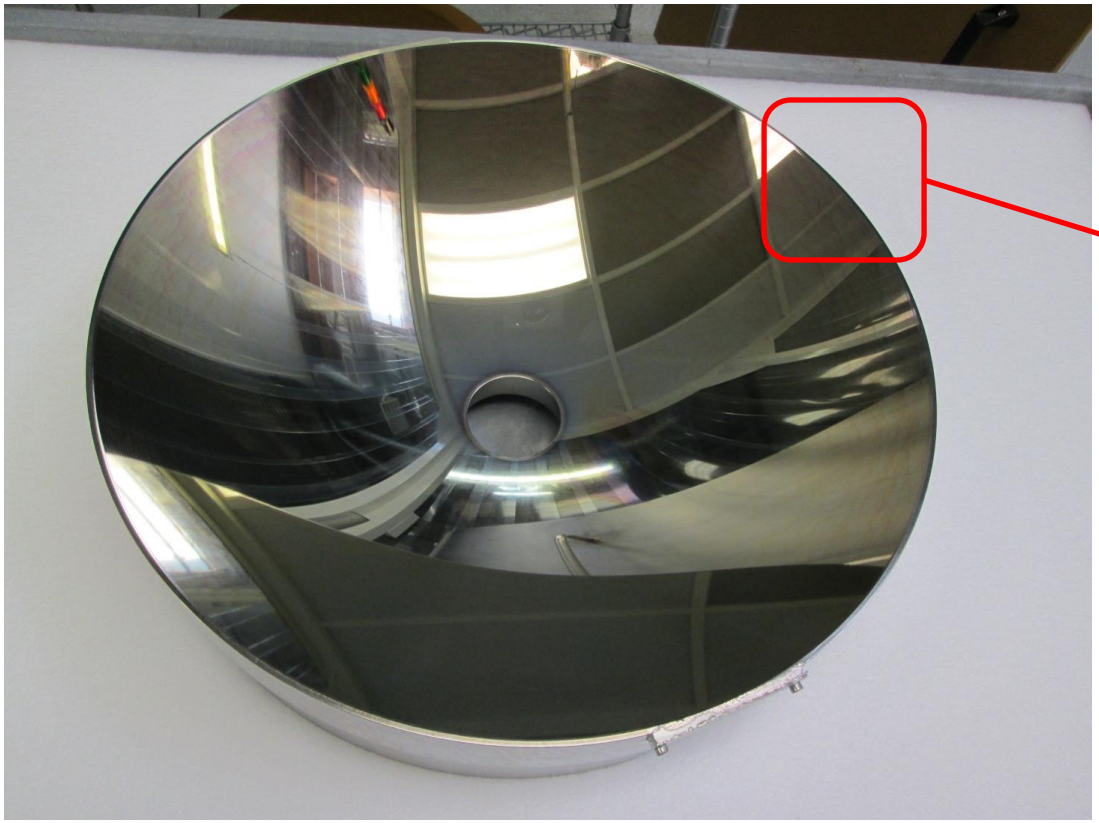


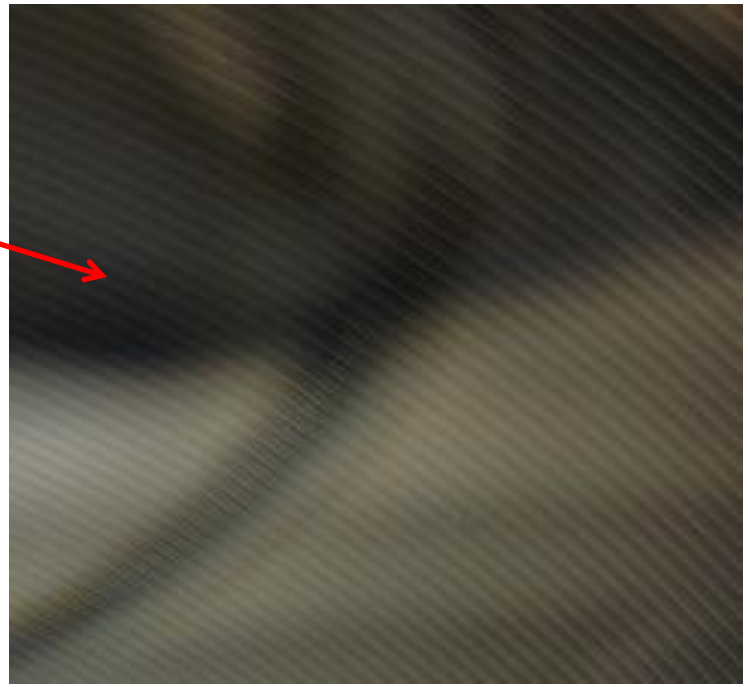
MACHINING & FIGURING

Process Flow



Demonstration Collector: ~410mm dia (NA ≳ 0.22)





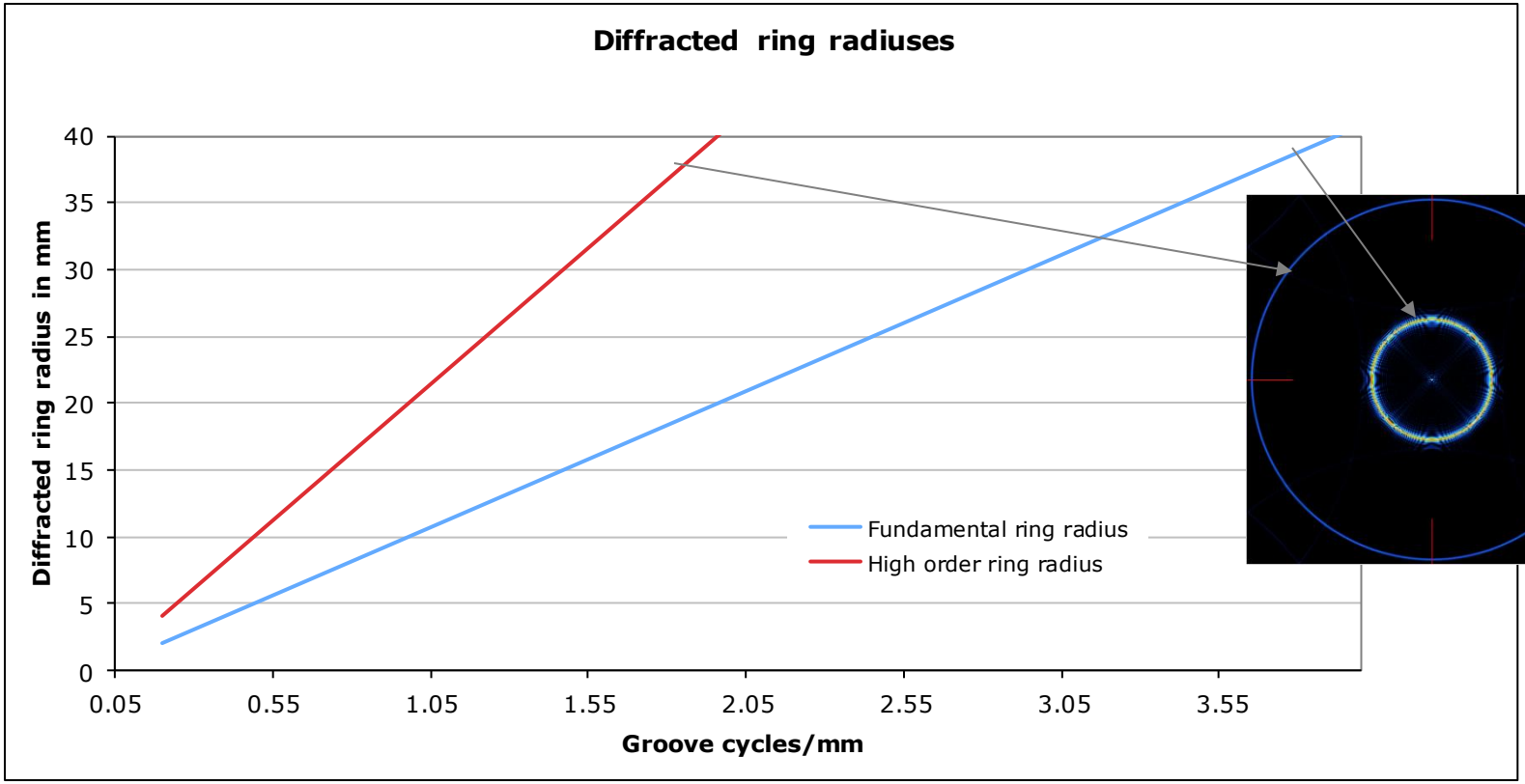
Grating structure

INFRARED REJECTION (IRR)

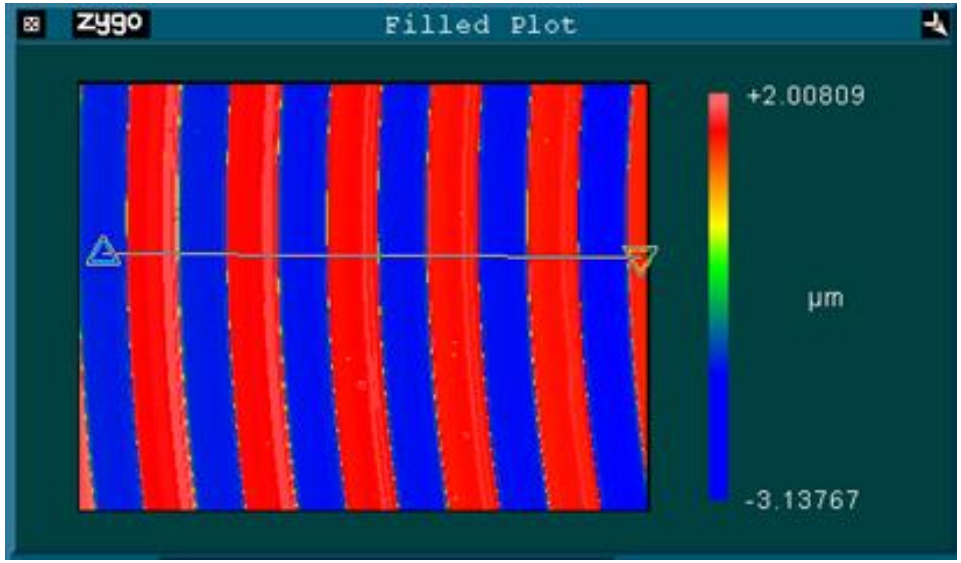
The theoretical performance of different grating types for IR rejection:

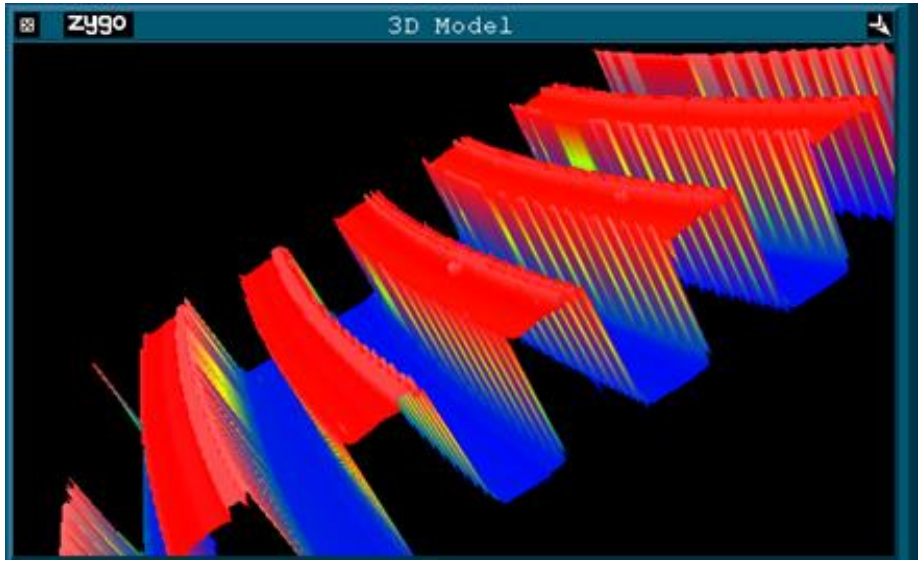
Physical mode	Zero order	Fundamental positive order +1	Fundamental negative order -1	+2 order	-2 order	+3 order	-3 order
Binary amplitude	25%	10.1%	10.1%	0%	0%	1.1%	1.1%
Sinusoidal amplitude	35%	6%	6%	0%	0%	5%	5%
2 phase levels	0%	40.5%	40.5%	0%	0%	4.5%	4.5%
4 phase levels	0%	81%	0%	0%	0%	0%	10%
8 phase levels	0%	94.9%	0%	0%	0%	0%	0%
16 phase levels	0%	98.7%	0%	0%	0%	0%	0%
Blazed phase	0%	100%	0%	0%	0%	0%	0%
Sinusoidal phase	12%	34%	34%	0%	0%	0%	0%

The grating period is optimized to provide sufficient separation of the 0th order and the +/-1st order.

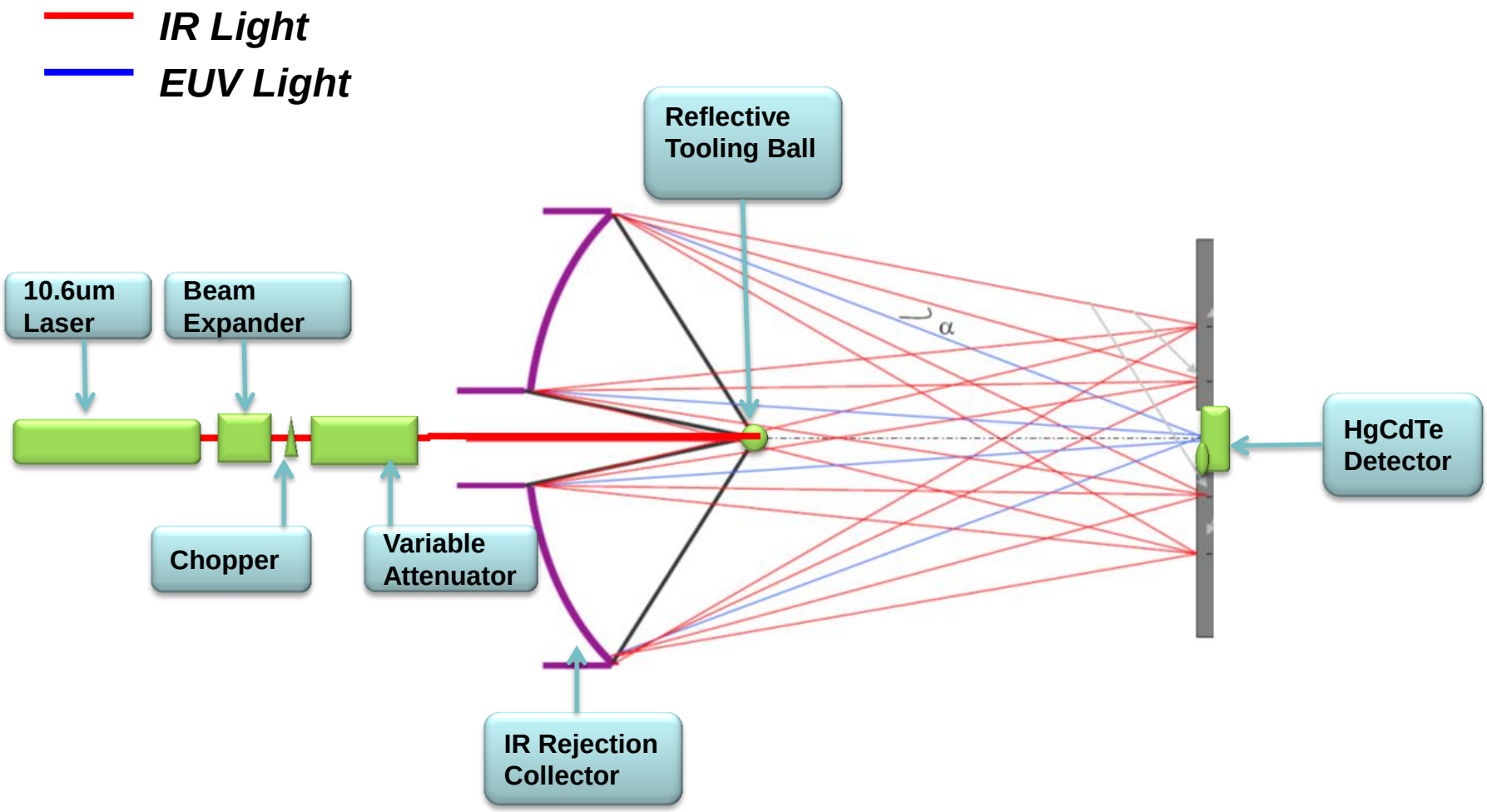


- Grooves contoured to the elliptical surface & are central-symmetric rings
- Groove pitch & depth vary with distance from collector center to account for changing angle of incidence

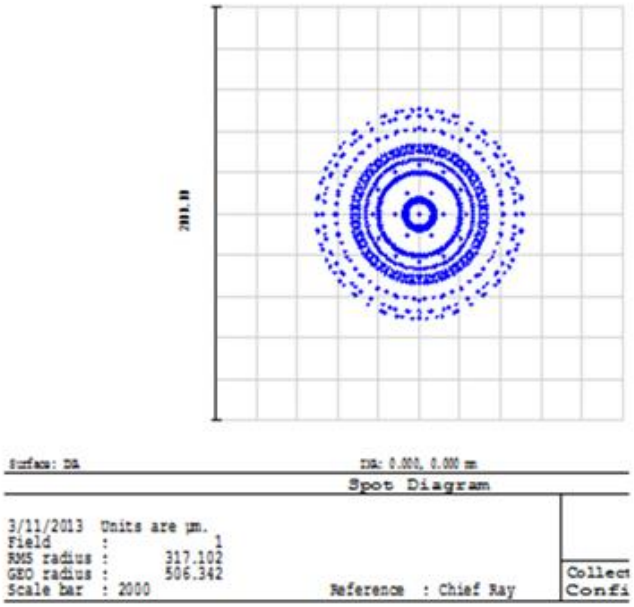


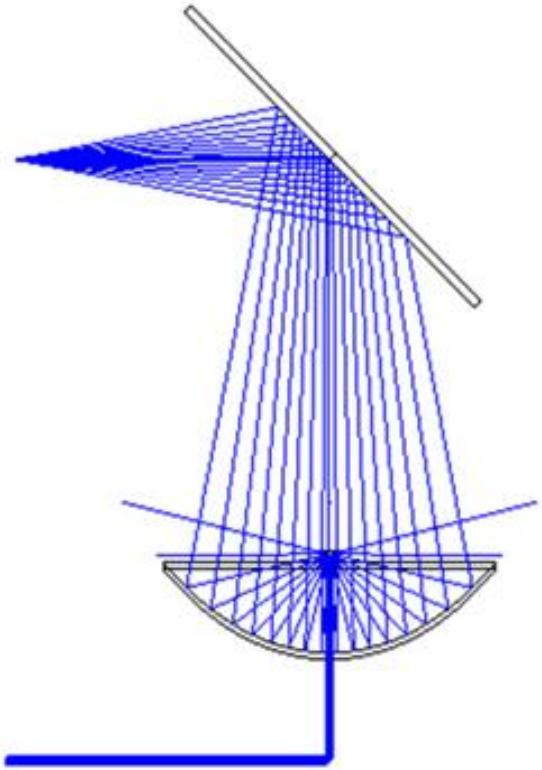


Integrated Optical Systems: IR Rejection Test Stand

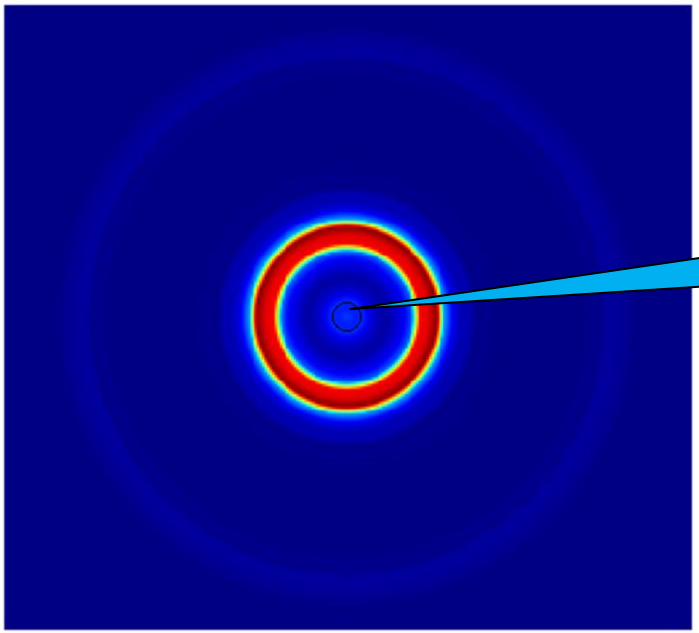


- IR rejection test uses an incoming collimated beam reflecting from a ½-in tooling ball to simulate a point source
- This method generates some spherical aberration which contributes blur to the zero order diffraction
- The nominal spot size of the blurred-zero order is contained within 1mm OD, well within the exit aperture
- Detector precision aligned to plane of IF
- IR rejection precision ±0.1%

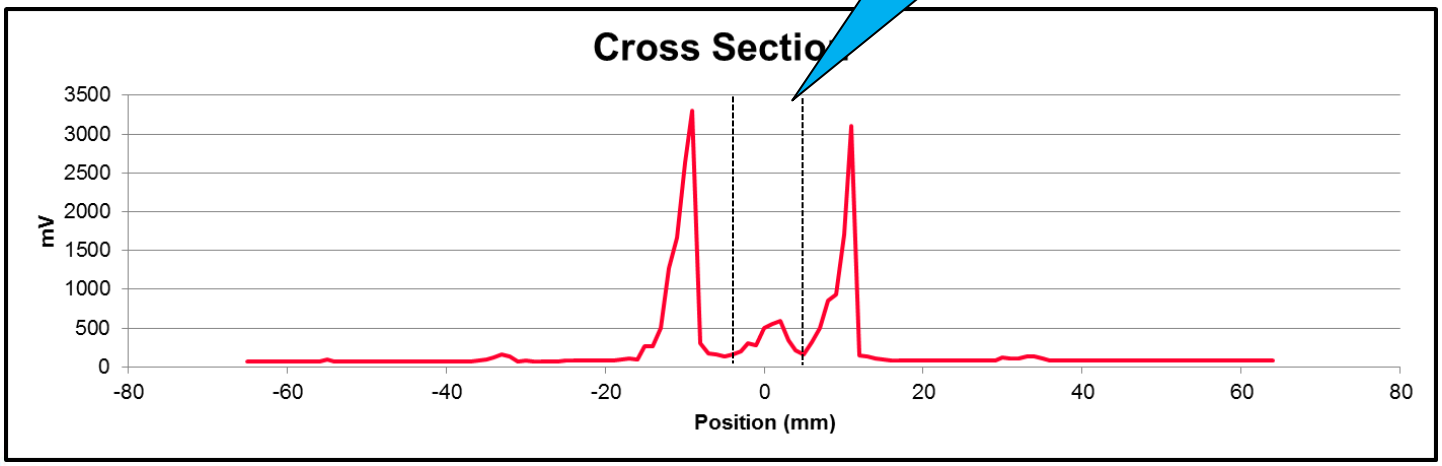




125X IR Suppression on Demo collector



Fraction of light in IF aperture is 0.8% ± 0.1% of total IR radiation



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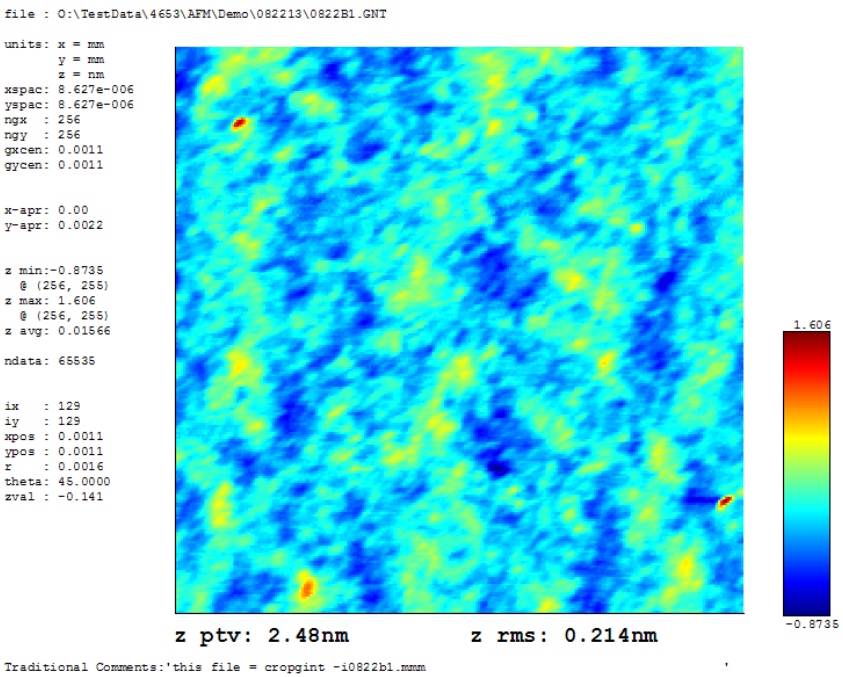
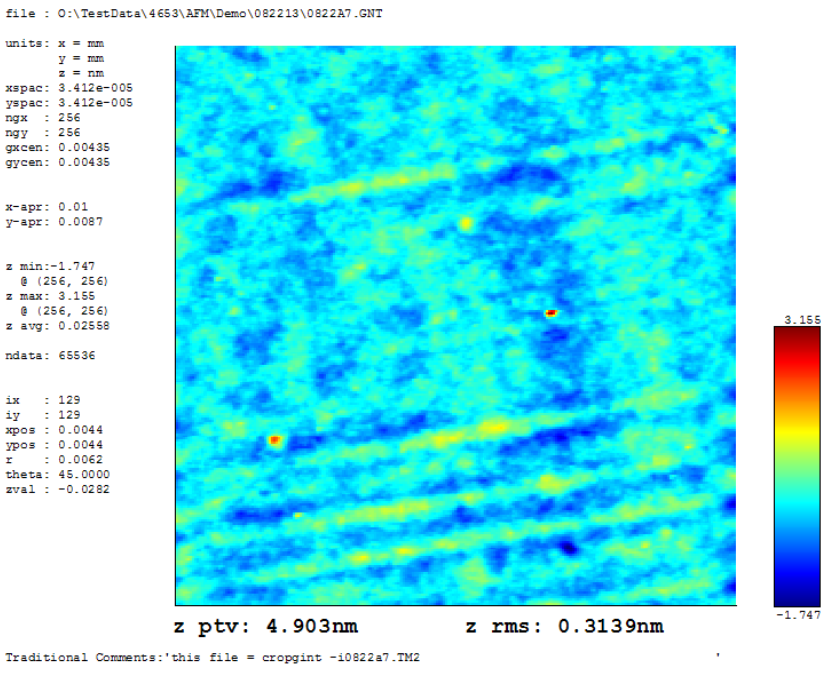
SMOOTHING LAYER

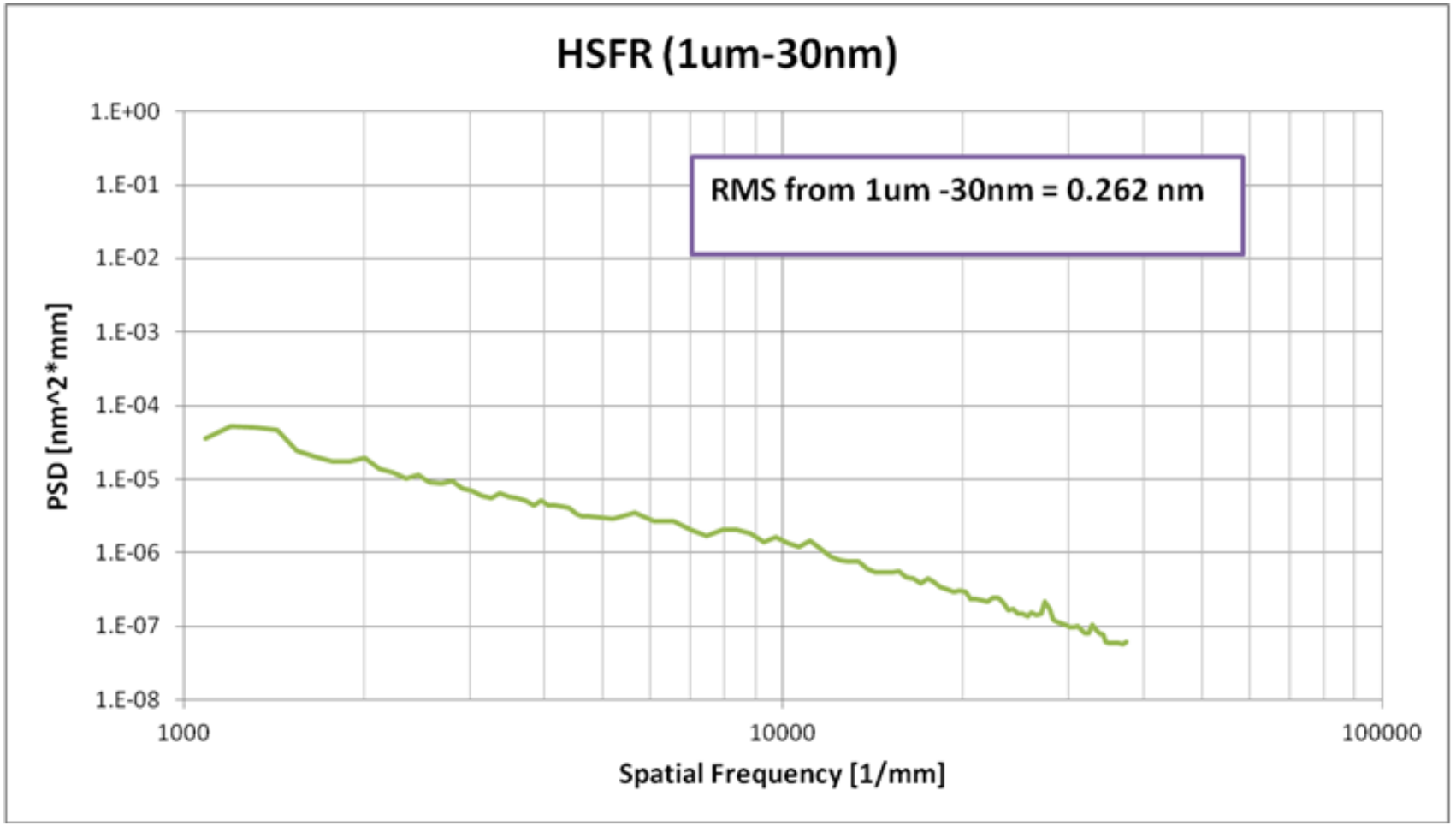
Glassy smoothing layer evaluated with AFM

0.14 – 0.29nm rms over 2.2µm



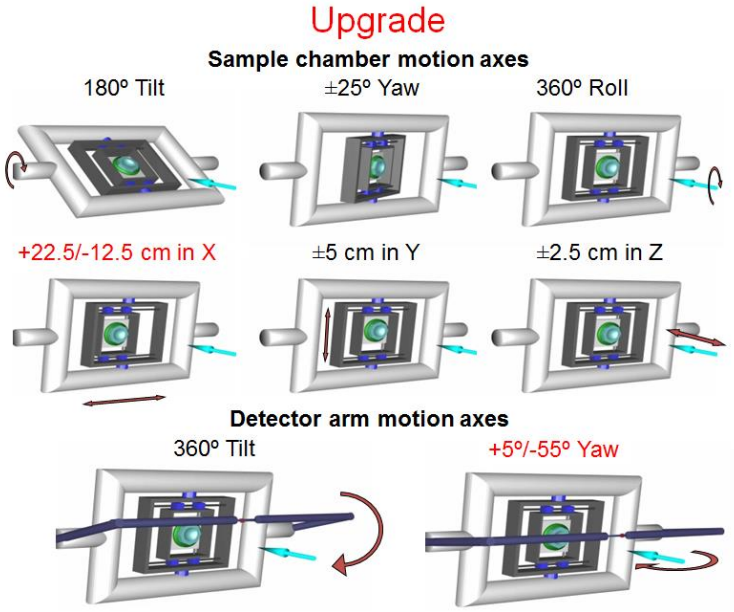
0.29 – 0.39nm rms over 8.7µm




HSFR (1um-30nm)
RMS from 1um -30nm = 0.262 nm
PSD [nm^2*mm]
1.E+00
1.E-01
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1.E-08
1000
10000
100000
Spatial Frequency [1/mm]

NIST REFLECTOMETER UPGRADE FOR LARGE OPTICS

EUV Reflectometry Facility at NIST



Sample Chamber

- **Samples up to 45 cm diameter, 40 kg mass.**
- **Six axes sample motion, three axes detector motion.**
- **UV spot size: 1mm x 1mm (FWHM)**
- **Can be fitted with external end-stations for assembled instrument calibration.**

Monochromator

- **VLS grating:**
  - **600 mm^{-1}, 7 nm - 35 nm**
- **Wavelength Uncertainty: 0.01 nm**
- **High throughput (P_{EUV} > 1 μW)**
- **Fixed exit slit**
- **Reflectivity uncertainty: Rp ~0.25% near 13.5 nm**

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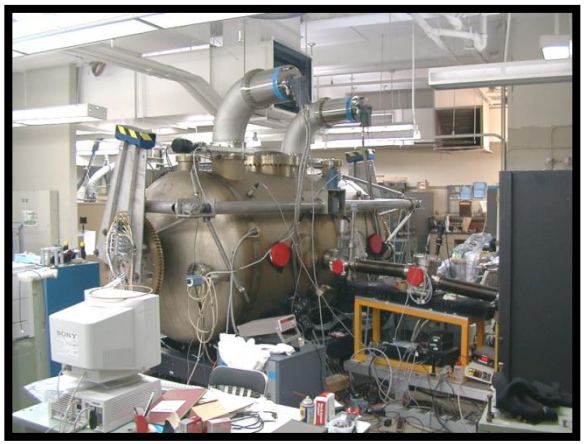
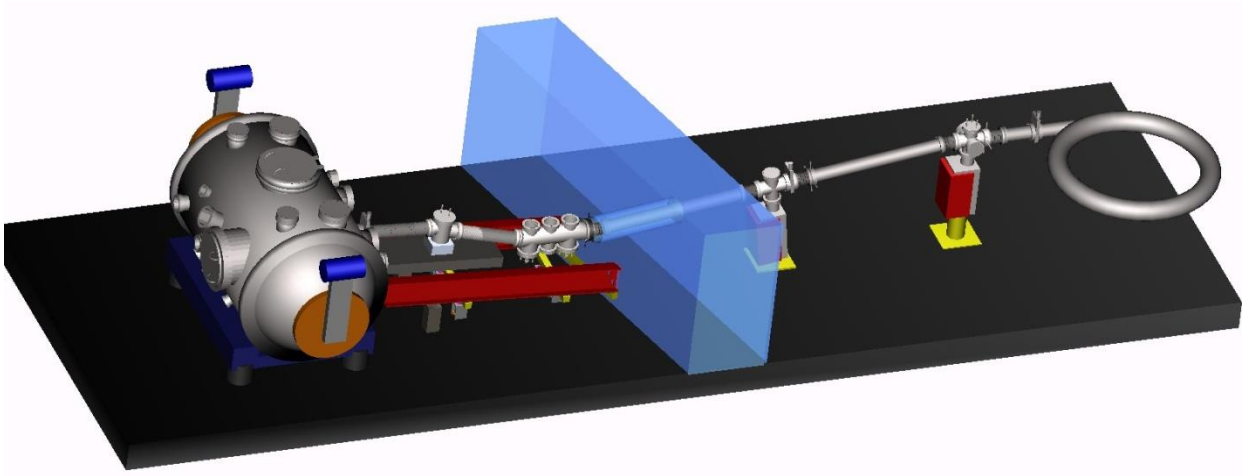
NIST upgraded to handle 45cm collectors





Goniometer can't be tilted far enough to make all measurements in vertical plane. Two angles should be set to add up to the incidence angle. It allows making measurements that simulate un-polarized light by setting reflection plane to 45° from vertical, thus converting this into un-polarized light (as from a plasma source) measurement.

A Zemax model was developed to predict the performance of the optic at various angles and positions. This model was used to place the optic and detector and to confirm alignment of the optic.

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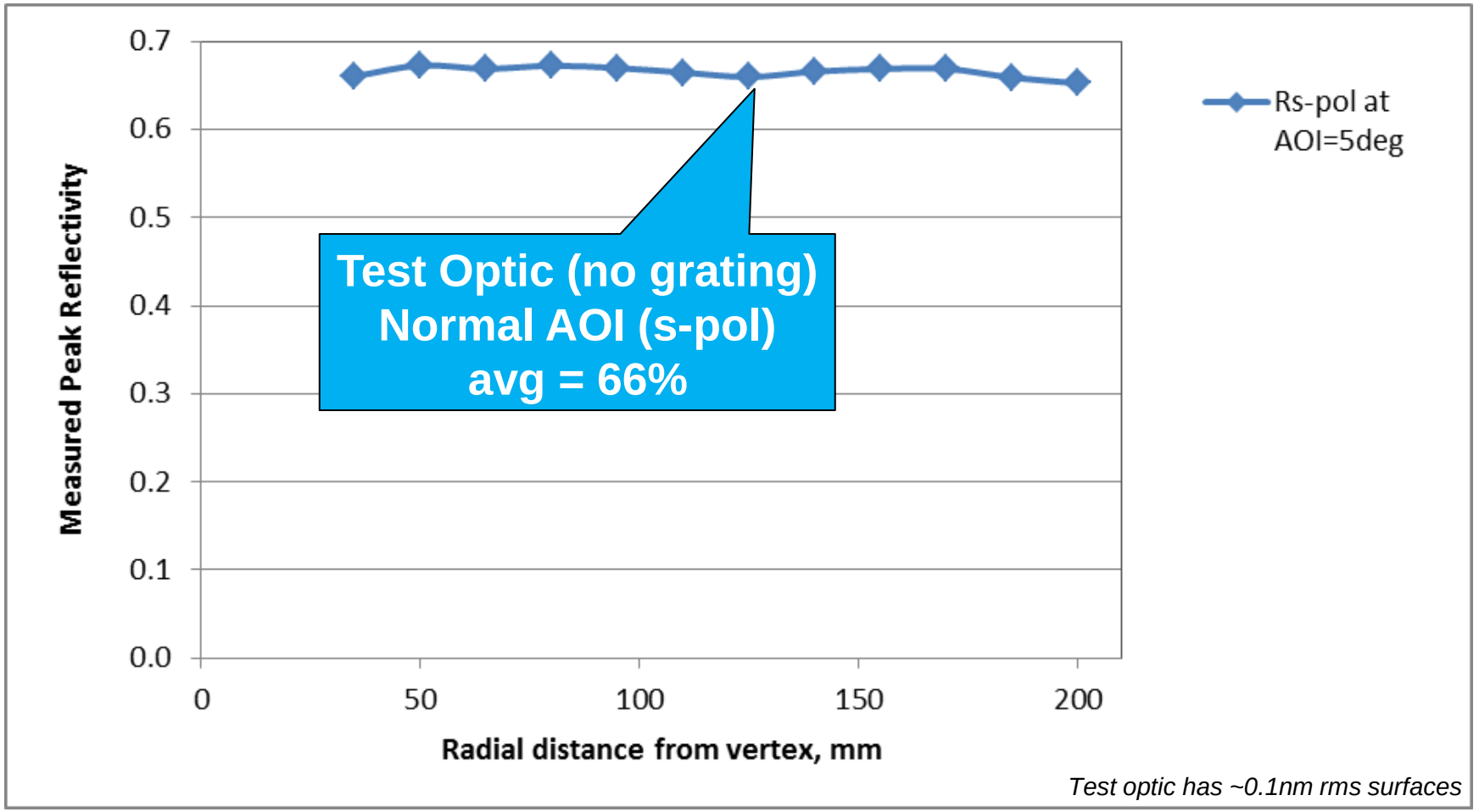
MULTILAYER RESULTS

Performance at Normal AOI

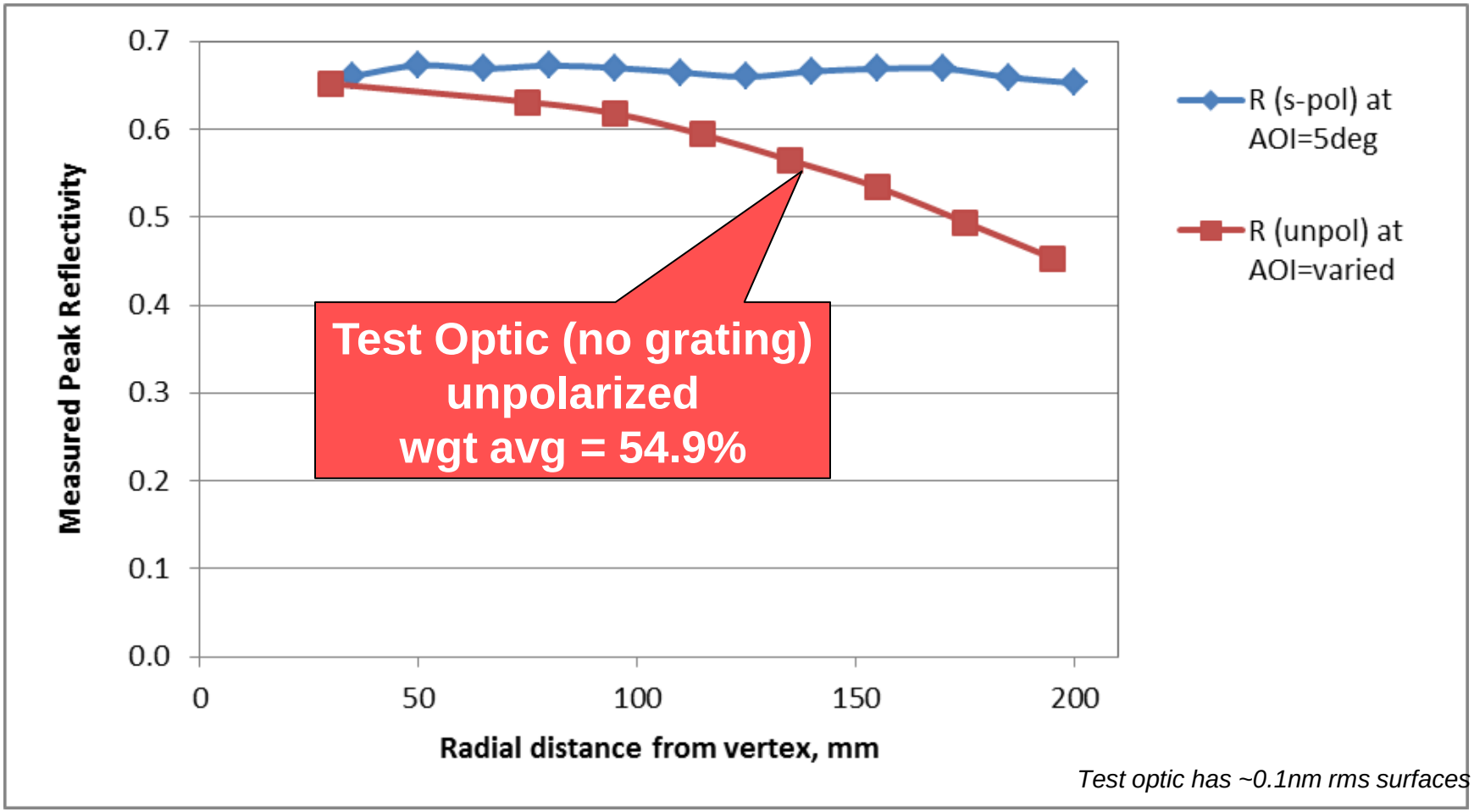
5º



Test optic has ~0.1nm rms surfaces

Performance at Design AOI

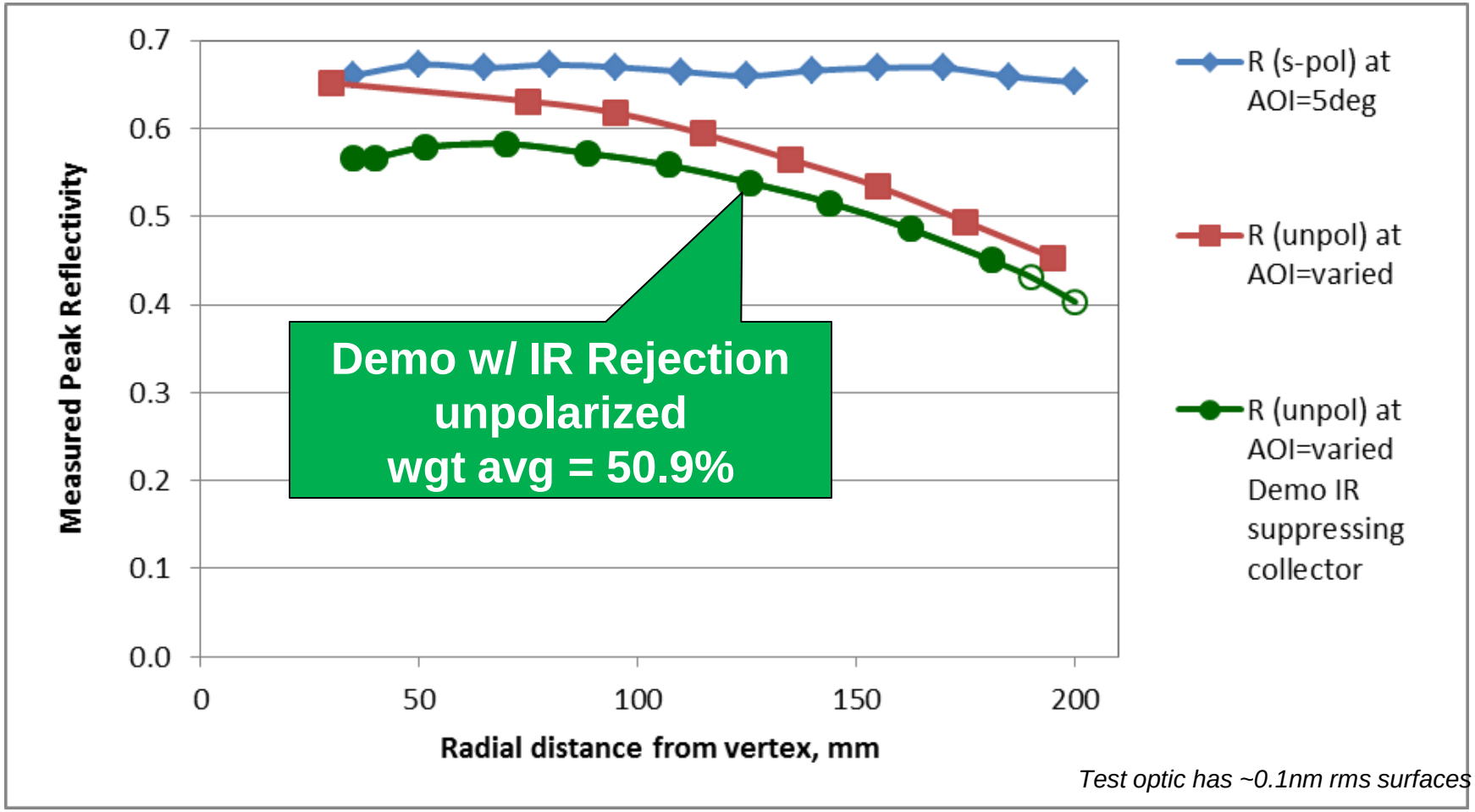
~5º to ~35º



Test optic has ~0.1nm rms surfaces

Performance at Design AOI

~5º to ~35º

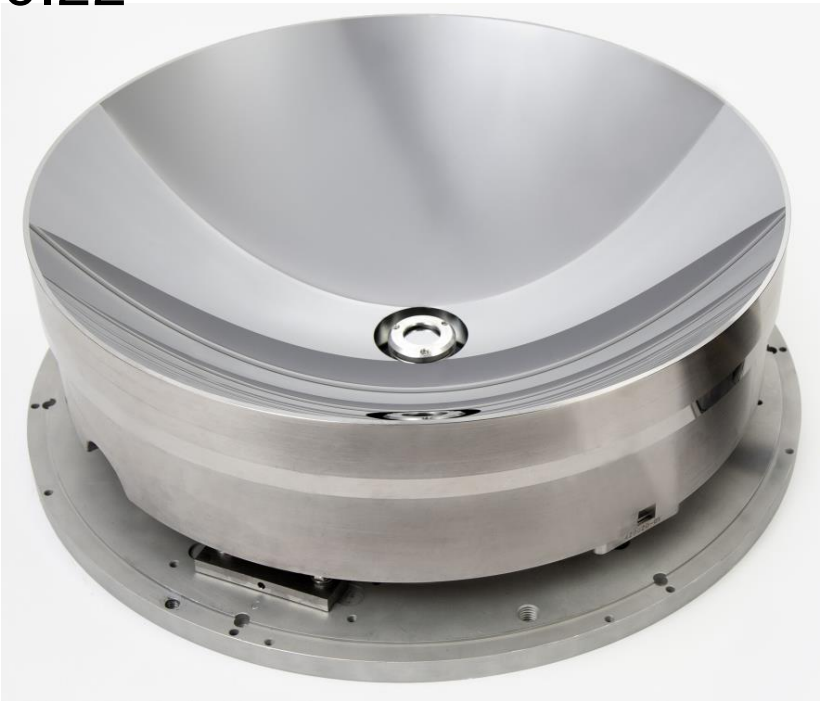


Test optic has ~0.1nm rms surfaces

SUMMARY

Current Results:

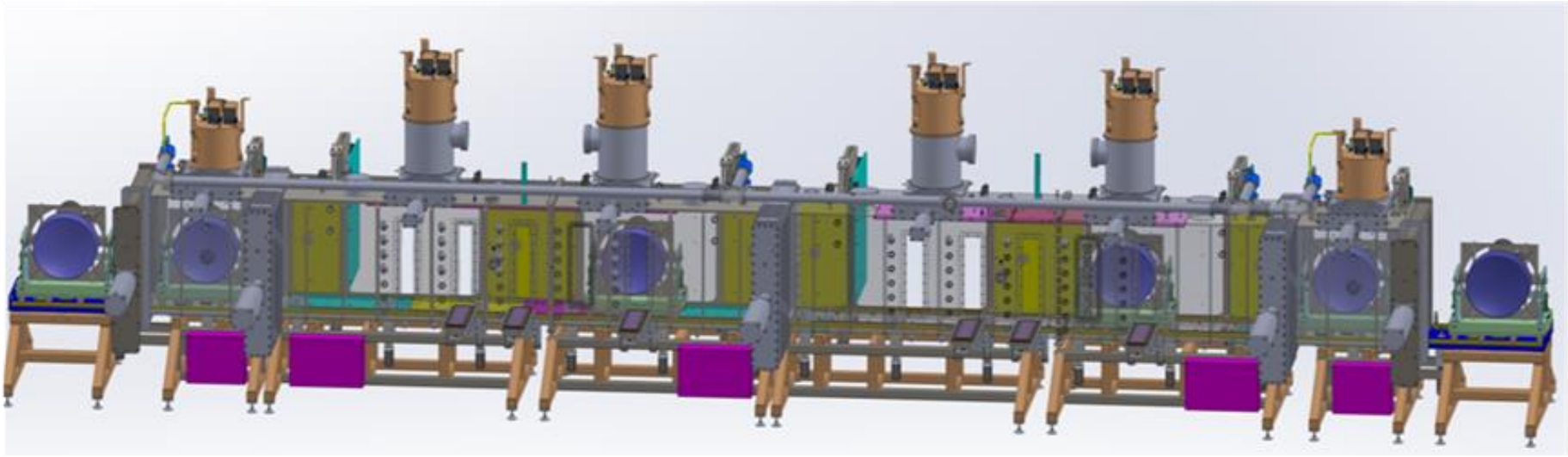
- Demo collector: 410mm, NA ≳ 0.22
- IR Suppression (grating) 125X
- Area-weighted EUV Rp 50.9%



Future Efforts:

- HVM-ready facility for 750mm optics (Jan-2014)
- Refurbishment Paths

Thank You



HVM (9-target) Inline Deposition System for 750mm Optics
— to be installed late 2013 —